High Quality 5 ps Pulse Generation at 10 Gbit/s Using a Fibre Bragg Grating Compensated Gain-Switched Laser Diode

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Abstract A fibre Bragg grating is designed to spectrally filter and perfectly compensate the chirped pulses from a gain-switched laser diode. This design is based on the exact characterisation of the intensity and phase profiles using an electro-optic pulse characterisation technique. This results in a compact pulse source that should produce high quality 5 ps duration pulses with a 50 dB pedestal suppression.

Introduction

A number of pulse sources have been used in high-speed OTDM experiments, including harmonically modelocked fibre lasers [1], modelocked semiconductor lasers [2], and gain-switched semiconductor lasers [3]. Gain-switched (GS) lasers are an attractive option as they are considerably simpler and more reliable than the other sources. However quality of the GS pulses makes them less desirable than modelocked pulse systems. GS pulses are typically 10-20 ps in duration, highly chirped and suffer from a timing jitter of around 5-10 ps [4]. The timing jitter on these pulses can be readily reduced to <1 ps with CW injection into the gain-switched laser from an external source [4] or by self-seeded operation [5]. The pulse duration can also be shortened by linearly compensating the intrinsic chirp on the GS pulses using an appropriate length of dispersion compensating fibre (DCF) [6]. This technique reduces the pulse duration to around 4-7 ps, however as the chirp is not completely linear across the pulse this produces compressed pulses that suffer from a pedestal that is 12-18 dB down on the peak intensity. This pedestal leads to a severe penalty when the pulses are multiplexed to higher bit-rates in an OTDM system.

Fibre Bragg Gratings (FBG) have also been used to linearly compensate the pulses from a GS laser diode [7]. We note that an appropriately designed FBG can be used to impose an arbitrary spectral intensity profile and compensate for both the linear and nonlinear chirp that is present on the GS pulses. Here we design a fibre Bragg Grating (FBG) whose group delay is designed to perfectly compensate the intrinsic chirp on the GS pulses and the spectral intensity profile is chosen such that the reflected pulse has a Gaussian profile. The grating is designed using a commercial package that implements a full time domain layer peeling algorithm. The design of the FBG is based on the complete characterisation of the intensity and phase of the GS pulses using spectrograms obtained with an electro-optic sampling technique [8].

Experimental Setup and Results

The compensated GS laser pulse source is shown in fig. 1(a). A 1555 nm DFB laser in a high-speed fibre pigtailed package (NEL NLK1552SSC) is gain-switched by driving with a 10 GHz sinusoid at 30 dBm RF power and a DC bias of 60 mA. An external CW DFB laser diode was injected into the GS laser via an optical circulator to reduce the timing jitter.

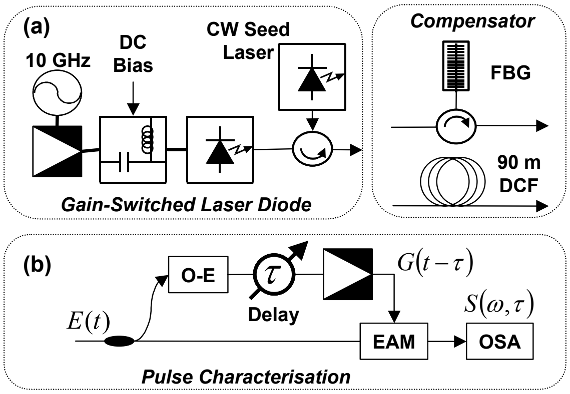

Fig. 1(a) Gain-switched laser diode setup with either a FBG or a DCF compensator. (b) The self-referenced EAM based pulse characterisation scheme.

These pulses were then characterised using a spectrogram generated by electro-optically sampling the pulse stream using an electro-absorption modulator (EAM). The sampling scheme shown in fig.1(b) picks off part of the optical pulse stream in an optical splitter and this signal undergoes optical-to-electronic conversion in a photodiode with a 20 GHz bandwidth and is then amplified to 4 Vp-p to drive the EAM. When the EAM is biased in its off state at –5.5 V a sampling window of 16 ps in duration is produced. The remaining optical signal E(t) is gated by the EAM and the output is spectrally resolved on an Optical Spectrum Analyser as a function of delay. This technique is very sensitive, as it does not require the use of an optical nonlinearity normally associated with similar techniques such as FROG [9], and ideally suited to the measurement of low spectral bandwidth GS pulses, which require a high-resolution spectrometer for accurate measurement. The pulse intensity and phase is obtained from the spectrogram using the numerical retrieval algorithm detailed in [9].

The temporal intensity and phase of the GS pulses characterised using the spectrogram technique are presented in fig. 2(a). The quality of the pulse retrieval is indicated by the excellent agreement between the retrieved spectra and the independently measured spectra shown in fig. 2(b). These pulses are around 11 ps in duration and possess a considerable negative chirp.

The designed FBG, shown in fig. 2(b), was based on this measurement. The grating group delay was calculated to exactly compensate the intrinsic chirp on the measured GS pulses whilst the spectral profile was designed such that the reflected optical pulse has a Gaussian profile.

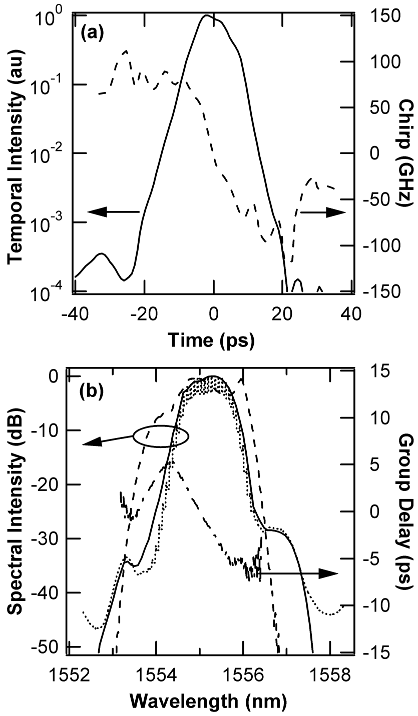

Fig. 2(a) Temporal intensity (solid line) and chirp (dashed line) for the uncompensated GS pulses. (b) Comparison between the retrieved (solid line) and directly measured (dotted line) spectra. Reflectivity (dashed line) and group delay (dash-dot line) for the FBG design are also shown.

Fig. 3 shows the calculated temporal pulse after compensation with the designed FBG. The compensated pulse is a transform limited Gaussian with a duration of 5 ps. For comparison simulated results using 90 m of DCF, a linearly chirped grating and a linearly chirped grating with spectral filtering are also shown. In comparison to the designed FBG where the pedestal is suppressed by more than 50 dB, these schemes only provide pedestal suppression of 15, 20 and 30 dB respectively. The advantage of spectral filtering is also seen when comparing the difference in pulse quality for the linearly chirped gratings with and without spectral filtering. Whilst the unfiltered pulse is 0.4 ps shorter, the pedestal suppression is 10 dB less than that of the filtered pulse.

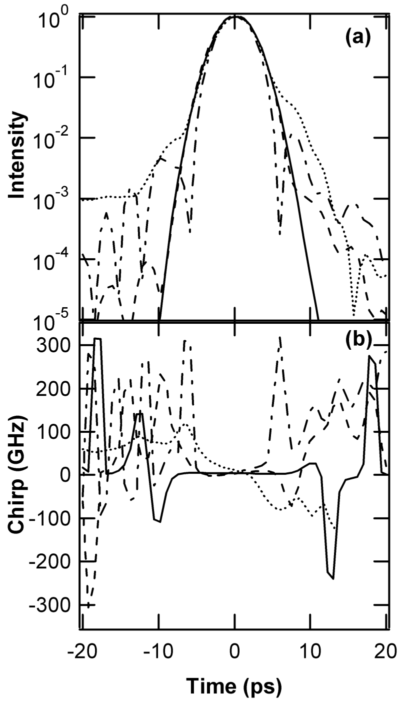

Fig. 3 Simulated temporal intensity (a) and chirp (b) profiles for the following compression schemes: matched FBG (solid); 90 m DCF (dotted); linearly chirped FBG (dash dot); linearly chirped+spectral filtering (dashed).

Conclusions

We have designed a FBG based on the measured intensity and phase profiles to shape and perfectly compensate the intrinsic chirp of gain-switched pulses. The measured intensity and phase profiles of the GS pulses were obtained using a highly-sensitive self-referenced optical sampling technique. Simulations showed that designed FBG produced compensated pulses of 5 ps in duration with a pedestal suppression in excess of 50 dB and an improved SMSR of 50 dB. This system should provide a compact solution to short pulse generation that is less prone to environmental drifts than conventional DCF based compensation and produces pedestal free pulses that are particularly suitable for high bit-rate OTDM applications.

References

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